STATEMENT

OF

PAICE CORPORATION

BEFORE THE:

SENATE COMMERCE COMMITTEE

DECEMBER 6, 2001

PRESENTED BY:

Theodore Louckes
Chief Operating Officer

Mr. Chairman,

Thank you for the opportunity to testify before your Committee regarding Corporate Average Fuel Economy (CAFE) issues. I serve as Chief Operating Officer of Paice Corporation. We are an American company (our offices are in Livonia, Michigan and Silver Spring, Maryland) with an American technological solution to the challenge of increasing fuel efficiency in passenger cars and light trucks. Paice is an acronym for power amplified (battery and traction motors) internal combustion engine. Paice Corporation has designed, patented[1, 2, 3, 4, 5] and tested a hybrid electric vehicle (HEV) powertrain system called the Hyperdrive™. I come before you today to explain how the Hyperdrive system works and to describe our estimates of its potential impact on fuel economy of automobiles subject to CAFE regulation.

The Hyperdrive System, a unique series/parallel hybrid electric powertrain for automobiles and light trucks, delivers a previously unattainable combination of fuel efficiency and vehicle performance at cost premiums that are reasonable when compared to conventional powertrains. Moreover, the Hyperdrive is well suited for a wide range of passenger vehicles, including SUVs, light trucks, and minivans. While other HEV designs can improve fuel economy or reduce emissions, no such design can produce these benefits in as wide a class of vehicles or at costs as favorable as the Hyperdrive. For these reasons, Paice Corporation believes that it has developed the only HEV powertrain system, to date, capable of being profitably produced on a large scale.

Paice Corporation has successfully demonstrated the benefits of the Hyperdrive System on a full-scale prototype powertrain on a dynamometer with funding from The Abell Foundation of Baltimore, Maryland, and is raising additional funding to incorporate the Hyperdrive into vehicles intended for large-scale production. The Company is currently in discussions with automakers throughout the world regarding production-intent vehicle prototype programs.

Paice is a small company that has attracted a unique group of highly experienced automotive industry officials for its development efforts. For example, Dr. Alex Severinsky, Chairman and Chief Executive Officer and founder of Paice Corporation, has been granted 21 U.S. patents, including three (3) on the Hyperdrive. He has unique technical knowledge of operations of electric motors, electronic power converters, electric storage batteries, and control of electro-mechanical systems. As for myself, prior to joining Paice Corporation where I am the Chief Operating Officer, I was with General Motors for 40 years, including a four-year military leave to participate in the Korean War, and retired as Chief Engineer of the Oldsmobile Division. Among other programs at GM, I was responsible for the development of the first overhead cam, 4-valve engine for American passenger cars and the introduction of the world's first air bag system.[6] Another of our staff, Nathanael Adamson, Executive Vice President, served Ford Motor Company for 32 years and gained domestic and international experience in product development, program control, marketing, and business management of consumer and industrial products in the automotive industry. In addition, David Polletta, Vice President of Engineering, has 18 years of experience in engineering and management of EV and HEV projects and 12 years of experience at Ford Motor Company as a supervisory engineer in commercial truck engines and powertrain engineering.[7]

On our board of directors, we have several former auto industry officials. For example, Robert Templin, a retired GM Executive, has over forty years of experience in the design, development, and production of automobiles and powertrains. Over the years, he has held such GM positions as Technical Director of the Research Laboratories, Chief Engineer of the Cadillac Motor Car Division, General Project Manager of Special Product Development, and Special Assistant (Engines) to the President of GM. In addition, George Kempton has over 40 years of management experience in automotive and industrial products, including powertrain components for commercial vehicles and most recently he left Kysor Industrial Corporation where he was Chairman and Chief Operating Officer. Finally, Robert Oswald who recently left his position as a member of the Robert Bosch GmbH's Board of Management, and Chairman, President and CEO of Robert Bosch's North American subsidiary Robert Bosch Corporation, after serving there for more than a decade.

Our testimony today is divided into several topics: first, an overview of the characteristics of the Hyperdrive powertrain system; second, modeling results that demonstrate the Hyperdrive powertrain system's potential for reducing fuel consumption in three selected vehicles (a compact car, a full-size car, and a large SUV); third, a discussion of why the Hyperdrive powertrain makes it possible to profitably commercially mass produce an HEV (and thereby deliver the fuel economy and emissions results that HEVs make possible); and fourth, a discussion of the implications of the Hyperdrive system for fuel consumption. It is important to note that powertrain developments at Paice Corporation continue at a rapid pace. What we present here is a current overview of our development effort that will change as we make further improvements and refinements to our system.

As will be discussed in greater detail below, the Hyperdrive system can increase fuel efficiency in the selected vehicles modeled for this testimony by approximately 50 percent. We encourage the Senate Commerce Committee to ask the Argonne National Laboratory to model our results to corroborate our conclusions regarding fuel economy and performance. We also encourage the Senate Commerce Committee to request that the Oak Ridge National Laboratory[*] estimate what impact the Hyperdrive system would have on future fuel consumption, based on the modeling results from Argonne. In this regard, Paice Corporation would welcome the opportunity to work with automakers and/or the federal government to produce a demonstration vehicle that can be tested to reconfirm the conclusions discussed here today and to more precisely determine the cost of producing such a system.

I. The Paice Hyperdrive System

Fundamental Principles

An auto industry executive was recently quoted as saying: "we can't dictate customer choice, nor should we try to[#]. This statement is widely accepted as a governing axiom in automotive marketing. To compete against current and future powertrains, any HEV system as well as the Hyperdrive must be at least equal, and even

[*] This data is based on a study conducted by Oak Ridge Laboratories. Davis, SC 2001. Transportation Energy Data Book: Edition 21, ORNL-6966, available at <http://www.ornl.gov/~webworks/cppr/y2001/rpt/111858.pdf>.

[#] Fuel Targets for Sport Utilities Pose Difficulties for Automakers, The New York Times, November 23, 2001, p. C1.

superior to existing powertrains in all respects. Only this will result in market forces choosing the adoption of fuel saving powertrain technology. Accordingly, our development of the Hyperdrive was guided by the following fundamental considerations:

- The system should run on readily available gasoline or diesel fuel.

- The internal combustion engine (ICE) should be used to convert liquid fuel chemical energy into mechanical energy, as it is the most efficient means yet discovered.

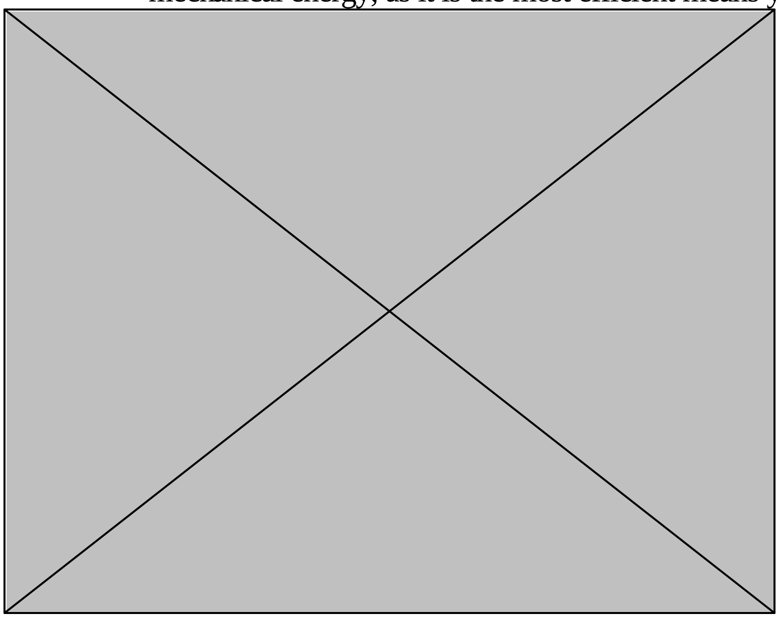

Fig. 1. Use of ICE in the Hyperdrive

- The system should use the ICE only in its most efficient operating region; that is, under those load conditions in which Brake Specific Fuel Consumption (BSFC) is minimized. In Figure 1 we present graphically how the ICE is used in the Hyperdrive in comparison with current powertrains.

- Use of the ICE in this way will result in increased fuel efficiency as well as improvements (i.e. reductions) in exhaust emissions. Emissions can also be reduced by use of advanced computer control of the engine air-fuel ratio, catalyst preheating and a simplified engine operating cycle (eliminating ICE transients). While a number of current production vehicles are already meeting California's Ultra-Low Emission Vehicle (ULEV) requirements, the Hyperdrive can assist in achieving this level in the full range of vehicles and at lower cost.

- Sophisticated software control algorithms must be employed to control powertrain without any need for an increase in driver skills or driver awareness.

- Customer expectations must be satisfied without compromise. Present levels of convenience of operation, and operating/ownership cost must be equal to or be better than those offered by present powertrains.

- Manufacturing raw material requirements must be satisfied by using the same rea materials already used in present high-volume automotive production, i.e. iron, lead, copper, aluminum and silicon. Special material needs, such as catalytic agents, must be no more critical than they are today.

- System flexibility and cost must be applicable over a wide range of vehicle weight allow the benefits to be achieved over the entire passenger vehicle market.

- Current restrictions imposed on design flexibility by vehicle space, weight, drag and architecture requirements should be reduced to allow more freedom for design variations.

- Physical size and arrangement of the drive components must be flexible enough to allow installation in existing body and chassis concepts to avoid the costs, lead times and investments in plants and equipment that radical new vehicle programs would require.

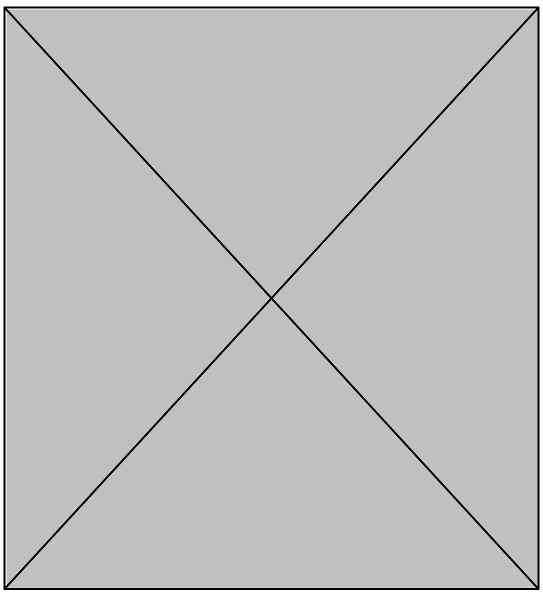

Fig. 2. Test prototype of the Hyperdrive

- Vehicle, powertrain and fuel system service requirements must be compatible with the skills, training and diagnostic capability available at the retail level.

Testing and Test Results

Based on these principles, Paice Corporation built and tested the Hyperdrive system (Figure 2) on a dynamometer load representing a typical 4,250 lbs. large passenger car. In Figure 2, we present arrangements and rating of components in the Hyperdrive powertrain system as tested and in Figure 3 we present some photographs from the testing.

Table 1 presents a summary of the fuel economy test results. To verify these results, we have measured energy losses in all parts of the Hyperdrive together with energy applied to the load, and compared this with the energy coming from the fuel. These results coincided within tolerances of measurements. This allowed us to calibrate our control software model, which we have used to determine the expected results of using the Hyperdrive system in other vehicles discussed below (a compact car, a full-size car, and a large SUV).

Hyperdrive Test Results		
	Conventional	Hyperdrive
City Driving (FUDS)	19 MPG	**38 MPG**
Highway Driving (HWFET)	33 MPG	**54 MPG**
Combined	24 MPG	**44 MPG**

Table 1. Summary of fuel economy test results

Key Technical Principle

The key technical principle underlying the Hyperdrive system is that it employs a unique method of control (use of the engine) that optimizes the operation of the internal combustion engine in hybrid electric vehicles.[1,2,3,4,5] This method of control results in the achievement of operational thermodynamic efficiencies[1] of 32-34% as compared to the recognized maximal attainable efficiency of 35% for spark-ignition internal combustion engines. By way of comparison, the internal combustion engine in conventional vehicles typically operates at overall efficiencies of around 20%. Our improved overall operating efficiency is supported by the configuration of components in the Hyperdrive, including a lead-acid battery system that stores the energy generated by the engine (and regenerated while braking), and high-power electric motors that propel the vehicle when the engine cannot be used in its most efficient operating region. Recent advancements in high voltage power semiconductors, coupled with extensive positive experience in new lead-acid battery applications, have provided the practical basis for the commercialization of our technology.

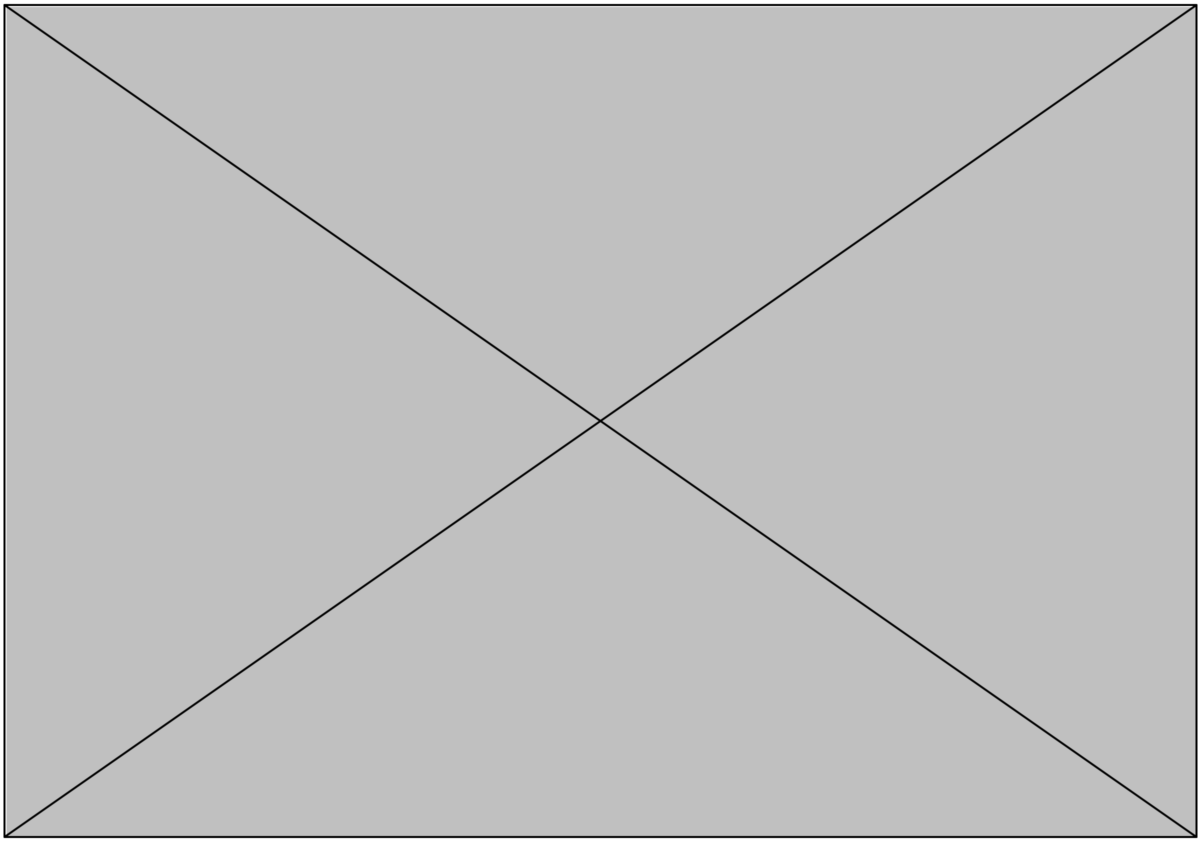

Fig. 3. Hyperdrive in the dynamometer test cell

How the Hyperdrive System Works

The internal combustion engine (ICE) of a conventional vehicle is required to deliver power under a wide range of loading as a function of driving condition. This is an inefficient way of producing mechanical power from the energy in gasoline or diesel fuel. If the ICE were allowed to operate *only* in its optimal operating region, *fuel efficiency improvements of roughly 50%* would be possible (depending on the size and type of vehicle and its intended application). This is the fundamental principle behind the Hyperdrive as is illustrated in Figure 1.

Paice achieves this high level of performance and fuel economy by introducing a battery system that captures the energy output of the ICE (which is operated only in its most efficient range) and an electric motor that uses this electrical energy to power the vehicle when the ICE cannot be used efficiently or when power requirements are higher than can be delivered by the ICE alone. The motor also acts as a generator to recover energy from the vehicle during deceleration. (There are other significant features of the Hyperdrive, but the foregoing is illustrative of the basic concept that results in the dramatic improvements in fuel economy.)

The operation of all of these components and their function is managed by the Paice Control Module, a multiprocessor with associated control software and embedded proprietary control algorithms. Through this patented method of control of the drive components, the Hyperdrive system improves powertrain efficiency by roughly 50% over conventionally powered vehicles (depending on vehicle type and application). Other than the Paice Control Module, the various hardware components in the Hyperdrive system already exist in one form or another in conventional vehicles. The differences lie in the relative sizes of components, their functional relationships and, most significantly, the software incorporating Paice's patented method of control, which enables the components to function as a highly efficient system. Thus, the Hyperdrive represents an evolutionary step in automobile technology, and does not require advanced development efforts or dramatic changes in manufacturing infrastructure.

Modes of Operation

There are four typical modes of operation that illustrate the basic functionality of the Hyperdrive: city driving, recharging during city driving, acceleration, and cruising on the highway. In addition to these four, there are a number of other modes defined in the control algorithm.

The Hyperdrive system includes a clutch – essentially a device that is either engaged or disengaged. The clutch must be engaged for the mechanical power from the engine to be delivered directly to the driving wheels. The most frequent condition controlling whether the clutch is engaged or disengaged is vehicle road load reflected on the engine shaft. If this load is sufficient for the engine to be used near its maximum efficiency, then the clutch is engaged. Otherwise, it is disengaged. Generally, the clutch *is not* engaged during low speed city driving and *is* engaged during rapid acceleration and highway driving.

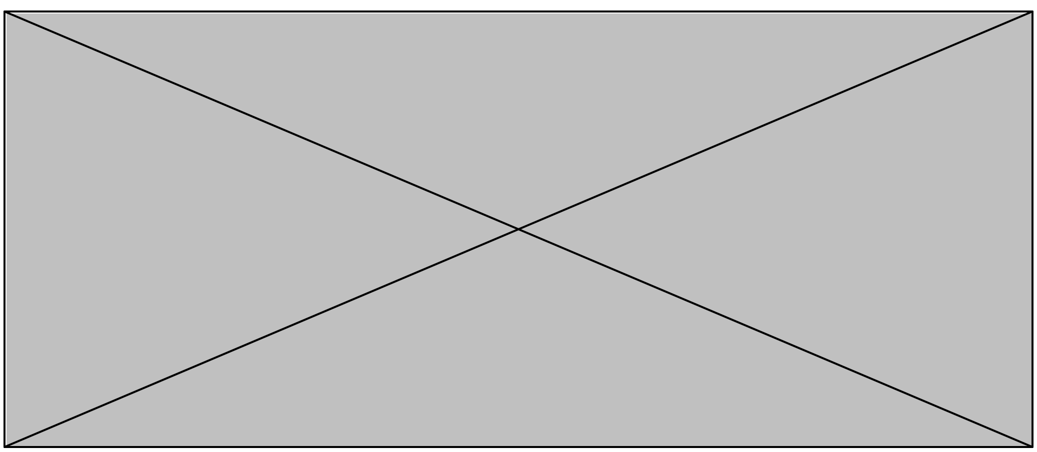

Fig. 4. Typical Hyperdrive operation in city driving.
A) An Electric Car; B) A Serial Hybrid

BAIn Figure 4, below, the clutch is disengaged in low speed city driving. In part A of Figure 4, the battery is above its minimum state of charge and the traction motor drives the vehicle. At this point, the vehicle is operating like an electric car. The battery is used in a narrow range of the state of charge, normally in 50% to 70% under partial state of charge (PSOC) condition, to assure long operating life. The amount of energy used in this electric-only mode is far below the PNGV definition of "dual mode hybrid". The Hyperdrive system operates like an electric car upon initial starting of the vehicle and during the intervals between times in which the battery is being charged.

Part B of Figure 4, shows a time period in city driving after the battery has been used to power the traction motors. Once the battery has reached its minimum state of charge, 50% or so, the starter/generator motor starts the engine. Upon starting the engine, a load is applied by the starter/generator motor (now operating as a generator) so that the engine runs close to its minimal BSFC operating condition. The power produced by the starter/generator is split. One part of it is delivered to the traction motor, making the Hyperdrive operate as a serial hybrid. The balance of the power is used to recharge the battery. Upon reaching the maximum level of battery charge, about 70%, the engine is stopped.

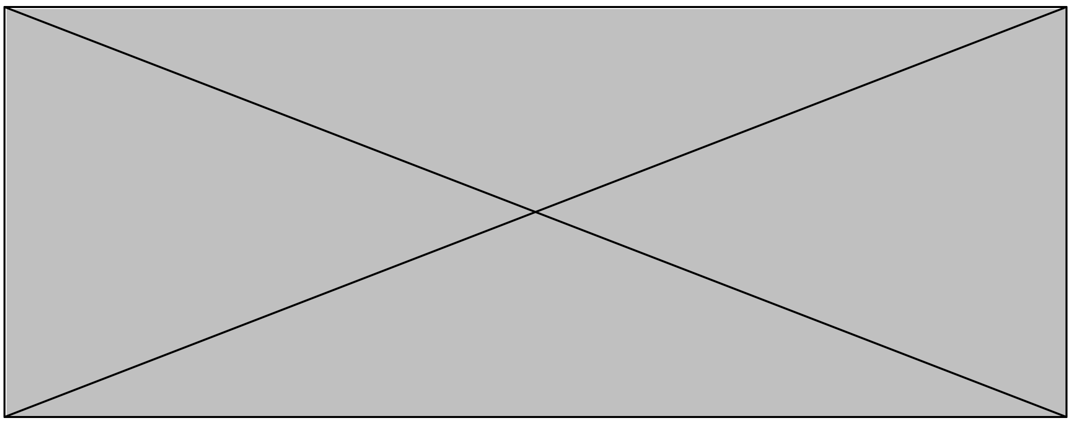

Fig. 5. Typical Hyperdrive operation in highway driving.
A) A conventional ICE powered car; B) Parallel Hybrid Mode

BAIn Figure 5, the clutch is engaged to accelerate onto and cruise on the highway. When time-averaged road load on the Hyperdrive is sufficient to place the engine in a region close to its minimum BSFC, the clutch is engaged. If the engine was off, it is started and synchronized by the starter/generator motor. At this point the engine begins to provide the average power demands of the vehicle. In this mode, the Hyperdrive acts as a conventional powertrain with its transmission in the direct drive position. This is depicted in Part A of Figure 5.

For vehicle acceleration or deceleration, all motors are used in a manner that minimizes energy loss in all electrical and electronic components. The Paice Control Module can assure this on a millisecond-by-millisecond basis. Acceleration with only the traction motor is shown in Part B of Figure 5. This is parallel hybrid mode. Engine torque is controlled to lag motor torque to assure operation with the most efficient air/fuel mixture. This allows for material reduction of engine-out emissions, not only for EPA test purposes but also under any driving conditions. Because electric motors provide excellent torque response to the driver's command, optimized levels of car responsiveness become possible, even varying the shape of this response as a function of the driver history and driving condition.

II. Modeling of Selected Vehicles

Effect of the Hyperdrive System on the Fuel Economy of a Fleet of Vehicles Subject to CAFE

Paice Corporation has modeled three vehicles (a compact car, a full-size car, and a large SUV) to provide benchmark data on expected fuel economy improvements in vehicles that can be produced in large volumes utilizing the Hyperdrive. The selection is limited to vehicles subject to CAFE regulation; that is, with Gross Vehicle Weight (GVW) under 8,500 lbs.

Vehicles subject to CAFE regulation in year 2000		
Vehicles	Units sold (in thousands)	Combined average fuel economy, mpg
Automobiles	**8,978**	**28 mpg**
Minicompact	19	26
Subcompact	1,789	31
Compact	2,398	30
Midsize	3,352	27
Large	1,297	25
Two Seater	122	26
SUV/Light truck	**8,307**	**21 mpg**
Small Pickup	1,072	22
Large Pickup	1,969	19
Small Van	1,272	23
Large Van	369	18
Small SUV	756	24
Medium SUV	2,167	20
Large SUV	702	18
All vehicles	**17,285**	**25 mpg**

Table 2: Summary of makeup and fuel economy of year
Source: Oak Ridge Transportation Energy Data Book

2000 automobile fleet.

In Table 2*, we present a summary of composition of vehicles subject to CAFE regulation that were sold in year 2000, along with the fuel economy average for each class. By combining sales volumes with combined fuel economy values, we calculated the overall

* This data is based on a study conducted by Oak Ridge Laboratories. Davis, SC 2001. Transportation Energy Data Book: Edition 21, ORNL-6966, available at <http://www.ornl.gov/~webworks/cppr/y2001/rpt/111858.pdf>.

combined fuel economy to be 24.6 mpg.

On the following pages, we show the results of our modeling for three particular vehicle classes represented in Table 2. These are a compact car (page 10), a full-size (large) car (page 11), and a large SUV (page 12).

Using the Hyperdrive system:

- a compact car exhibits an increase from
  31 to 45 mpg (a 45% improvement);
- a full-size car exhibits an increase from
  27 to 39 mpg (a 44% improvement); and
- a large SUV exhibits an increase from
  16 to 26 mpg (a 62% improvement).

We believe that these modeling results represent the type of increase that all vehicles subject to CAFE can produce using our powertrain.

Hyperdrive in a Compact Car Performance Comparison			
		Conventional	Hyperdrive
Engine			
Type		2.0L	1.6L Turbo
Peak Power		100 kW	95 kW
Motor			
Type		N/A	Induction
Continuous		N/A	8 kW
Peak		N/A	33 kW
Generator			
Type		N/A	Induction
Continuous		N/A	12 kW
Battery Pack			
Type		N/A	Lead-Acid
Modules		N/A	8
Voltage		N/A	400 V
Capacity		N/A	4 Ah
Weight		N/A	85 kg
Gearing			
Transmission Type		Auto 3 Speed	N/A
Generator Ratio		1	1
Motor Ratio		N/A	2.333
Final Drive Ratio		3.55	4.1
Fuel Economy			
ETW[1]		2,875 lbs.	3,000 lbs.
City		26 mpg	**41 mpg**
Highway		40 mpg	**50 mpg**
Combined		31 mpg	**45 mpg**
W.O.T.[2] Performance @ ETW			
Top Speed		> 105 mph	> 105 mph
0-60 MPH		9.2 sec.	9.0 sec.
55-75 MPH		6.7 sec.	5.0 sec.
35-55 MPH		4.2 sec.	3.7 sec.
Gradeability @ 3,875 lbs. GCW[3]			
	Objective		
@ 80 mph	5.5 %	7.9 %	8.5 %
@ 65 mph	7 %	16.5 %	8.9 %
@ 45 mph	10 %	17.5 %	10.1 %
Starting Grade	30%	> 30%	> 30%

[1] ETW – Emission Test Weight
[2] W.O.T. – Wide Open Throttle
[3] GCW – Gross Combined Weight

Table 3 Compact Car Performance Comparison

Compact Car

In Figure 6, we present the configuration of components in the Hyperdrive in a compact car. Given this configuration, in Table 3, we present a comparison of performance between a conventional compact car and a similar car with the Hyperdrive. For this comparison, we specifically selected a *top performer* in both driving characteristics and fuel economy.

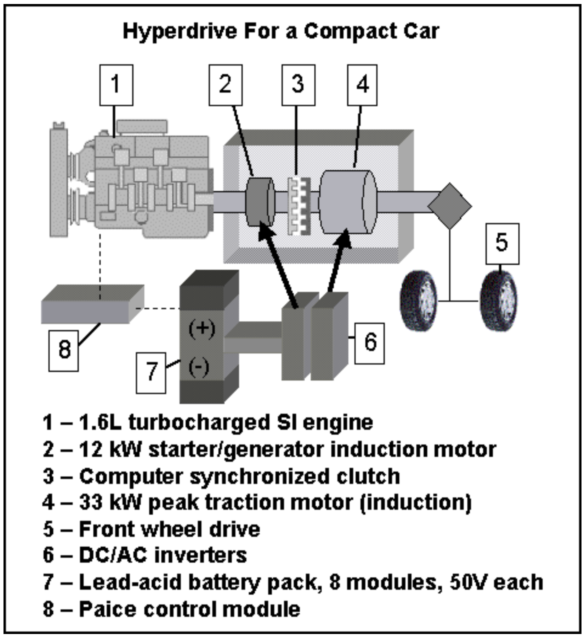

Fig. 6 Configuration of Components in the Hyperdrive in a Compact Car

It is important to note that combined fuel economy is improved from 31 to 45 mpg, or 45%. The passing performance is better with the Hyperdrive, accelerating from 55 to 75 mph in 5 seconds versus 6.7 seconds. Gradeability with the Hyperdrive on a continuous basis is better at 80 mph and otherwise meets requirements of the auto industry.[*]

While the Hyperdrive car is a little heavier than its conventional counterpart (125 lbs. in total), this difference is already factored into the fuel economy results. We believe that implementation of the Hyperdrive in a compact car will meet or exceed customer expectations for performance and provide 45% improvement in fuel economy.

[*] As an illustration of the significance of gradeability standards, climbing even a 10% grade at 45 mph for 5 minutes will elevate the vehicle by approximately 2,000 feet, or as high as a 160-story building.

Hyperdrive in a Full-Size Car Performance Comparison			
		Conventional	Hyperdrive
Engine			
Type		3.0L	2.0L Turbo
Peak Power		100 kW	95 kW
Motor			
Type		N/A	Induction
Continuous		N/A	12 kW
Peak		N/A	45 kW
Generator			
Type		N/A	Induction
Continuous		N/A	16 kW
Battery Pack			
Type		N/A	Lead-Acid
Modules		N/A	12 x 50 V
Voltage		N/A	600 V
Capacity		N/A	4 Ah
Weight		N/A	110 kg
Gearing			
Transmission		Auto 4 Spd	N/A
Generator Ratio		1	1
Motor Ratio		N/A	2.333
Final Drive Ratio		3.77	4.25
Fuel Economy			
ETW[1]		3,750 lbs.	3,875 lbs.
City		22 mpg	**35 mpg**
Highway		35 mpg	**45 mpg**
Combined		27 mpg	**39 mpg**
W.O.T.[2] Performance @ ETW			
Top Speed		> 105 mph	> 105 mph
0-60 mph		8.2 sec.	8.2 sec.
55-75 mph		5.7 sec.	4.4 sec.
35-55 mph		3.6 sec.	3.3 sec.
Gradeability @ 5,500 lbs. GCW[3]			
	Objective		
@ 80 mph	5.5 %	10.1 %	6.3 %
@ 65 mph	7 %	17.3 %	8.9 %
@ 45 mph	10 %	18 %	10.1 %
Starting Grade	30%	> 30%	> 30%
[1] ETW – Emission Test Weight [2] W.O.T. – Wide Open Throttle [3] GCW – Gross Combined Weight			

Table 4: Hyperdrive performance comparison in a full-size car

Full-Size (Large) Car

Next, in Figure 7, we present the configuration of components of the Hyperdrive in a full-size (large) car. Again, we specifically selected a *top performer* in fuel economy. In Table 4, we present a comparison of performance between a conventional full-size car and a similar car with the Hyperdrive.

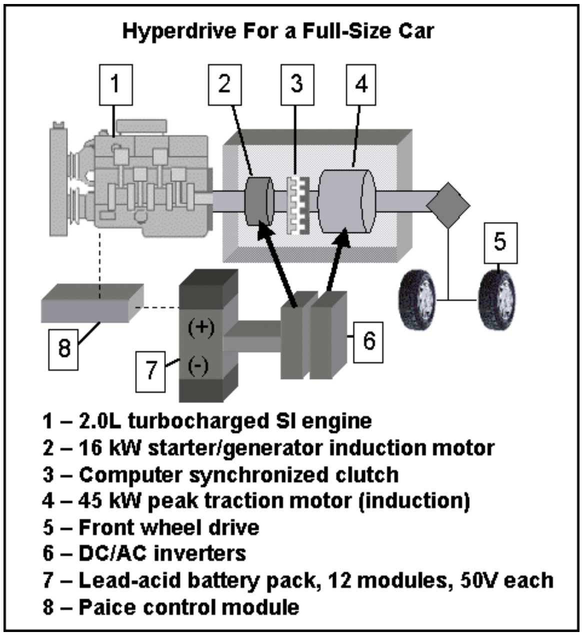

Fig. 7 Configuration of Components of the Hyperdrive in a Full-Size (Large) Car

As shown here, combined fuel economy improves from 27 to 39 mpg, or 44%. Again, passing performance is better: 4.4 seconds versus 5.7 seconds. The weight of the Hyperdrive vehicle is 125 lbs. greater than its conventional counterpart and this has been factored into our findings. We believe that implementation of the Hyperdrive in a full-size (large) car will meet or exceed customer expectations for performance and provide 44% improvement in fuel economy.

Large SUV

Figure 8 shows the Hyperdrive modeled to represent a large SUV with the Gross Vehicle Weight of 8,500 lbs., the *highest weight vehicle subject to CAFE regulations*. In this configuration, the Hyperdrive replaces the mechanical 4x4 drive with an electrical component and, because of a large difference in load range, we use a two-speed automatic transmission. In Table 5, we present a comparison of performance between a conventional large SUV and one equipped with the Hyperdrive. Importantly, unlike other HEV designs that must compromise performance, with the Hyperdrive system there is no change in trailer towing capacity.

Hyperdrive in a Large SUV (8,500 lbs. GVW[1]) - Performance Comparison		
	Conventional	**Hyperdrive**
Engine		
Type	5.4L	3.0L Turbo
Peak Power	194 kW	205 kW
Both Traction Motors		
Type	N/A	Induction
Continuous	N/A	15 kW
Peak	N/A	75 kW
Generator		
Type	N/A	Induction
Continuous	N/A	19 kW
Peak	N/A	19 kW
Battery Pack		
Type	N/A	Lead-Acid
Modules	N/A	16 x 50 V
Voltage	N/A	800 V
Capacity	N/A	11 Ah
Weight	N/A	250 kg
Gearing		
Transmission Type	Auto 4 Speed	Auto 2 Speed
Generator Ratio	1	1
Motor Ratio	N/A	2.9
Final Drive Ratio	3.55	4.1
Fuel Economy		
ETW[2]	5,750 lbs.	5,750 lbs.
City	14 mpg	**25 mpg**
Highway	22 mpg	**27 mpg**
Combined	16 mpg	**26 mpg**
W.O.T.[3] Performance @ ETW		
Top Speed	> 110[4] mph	> 110[4] mph
0-60 mph	9.6 sec	7.7 sec
40-60 mph	5.4 sec	3.6 sec
Gradeability @ 13,500 lbs. GCW[5]		
@ 80 mph	3.5 %	3.2 %
@ 65 mph	7.0 %	8.2 %
@ 45 mph	7.7 %	8.5 %
Starting Grade	26 %	26%

[1] GVW – Gross Vehicle Weight. CAFE regulation limit is 8,500 GVW.
[2] ETW – Emission Test Weight
[3] W.O.T. – Wide Open Throttle
[4] Tire rating limited
[5] GCW – Gross Combined Weight

Table 5: Large SUV Performance Comparison

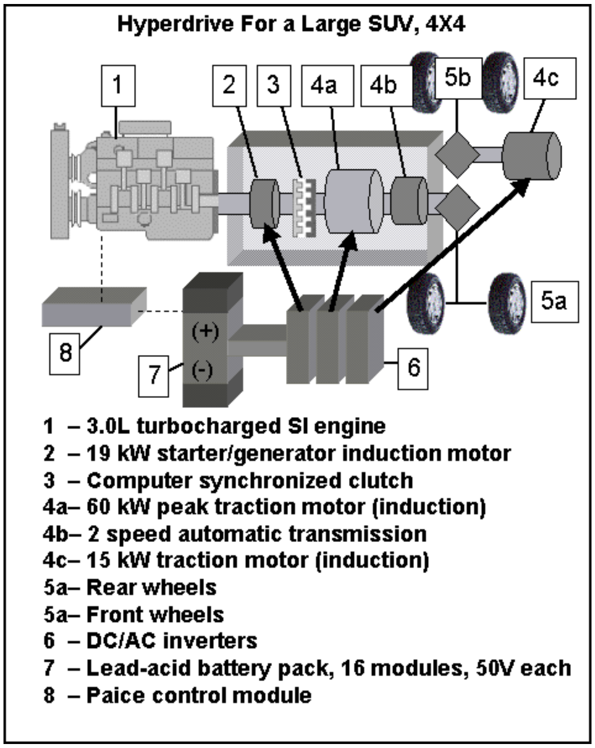

Fig. 8 Configuration of Components in Hyperdrive in a large SUV

Combined fuel economy is improved from 16 to 26 mpg, or 62%. Acceleration with the Hyperdrive SUV is markedly superior, accelerating from standstill to 60 mph in 7.7 seconds versus 9.6 seconds. Top speed is limited by tire rating. Gradeability meets the requirements of the auto industry in the conventional SUV. We believe that implementation of the Hyperdrive in a large SUV will meet or exceed customer expectations for performance and provide 44% improvement in fuel economy. Unlike other HEV designs, the Hyperdrive does not need to eliminate or greatly reduce trailer-towing capacity in order to provide the fuel consumption benefits desired.

III. Economics

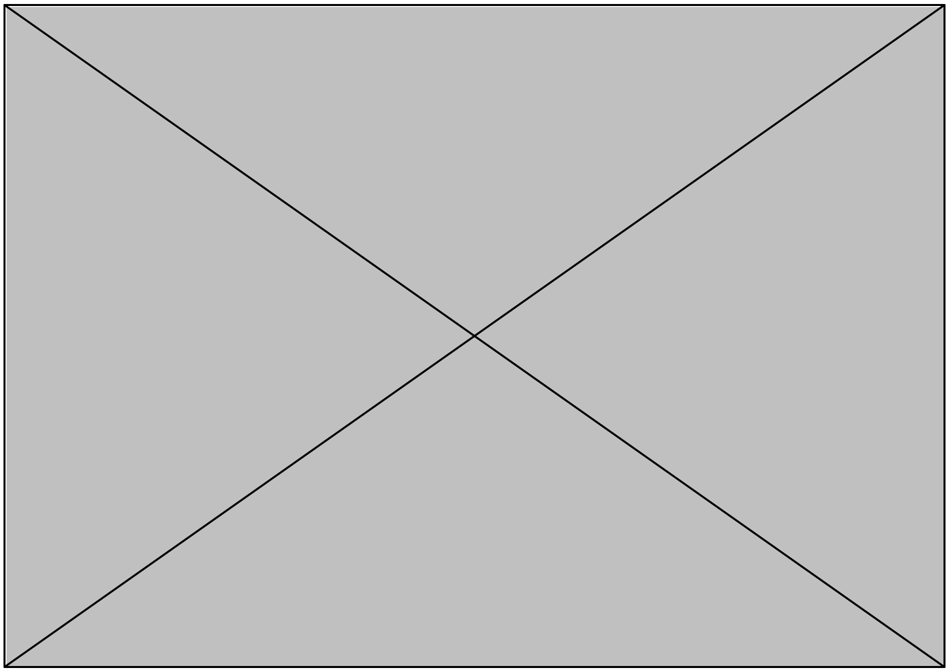

Figure 9: Enabling Technology "Chain Reaction"

We believe that a Hyperdrive vehicle can be produced with the same as or better performance characteristics than conventional vehicles, and with improvements in fuel efficiency and emissions, without substantially increasing cost. For example, Paice Corporation believes that the Hyperdrive could cost approximately $1,700 more than the conventional powertrain that it would replace in the large SUV application. Sources of data for this estimate came from prior experience of auto industry suppliers, new components suppliers and from our own experience. To further refine our cost estimates we are currently establishing a program to build a demonstration vehicle with all of the components specifically designed for their intended use by qualified automotive suppliers.

As an illustration of life cycle cost savings, the fuel economy benefit for the large SUV is 10 mpg. Thus, as a rough estimate, if the vehicle is driven 12,000 miles per year (average for American drivers) and has an expected life of 10 years, this fuel economy improvement will yield approximately 2,900 gallons in fuel savings.[*]

The decision as to whether the fuel savings justify the increased manufacturing cost is, of course, not purely quantitative. Evaluation of the secondary effects, however, is not within the expertise of the Paice team.

[*] In its report "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards", the Congressionally-authorized National Academy of Sciences (NAS) CAFE Study Panel evaluated break-even fuel efficiency using two evaluation cases. Case 1 assumed that a vehicle is driven 15,600 miles in its first year of service, decreasing 4.5% for each of the remaining years of its 14-year services life. This results in total mileage of 165.000 over the vehicle's assumed 14-year life. For Case 1, the CAFE Study Panel also assumed a current gasoline cost of $1.50 and applied a 12% discount rate to render a current year present value analysis. (The panel also applied an additional discount to the reported EPA mileage (15%) and assumed a penalty for future vehicle weight gains (3.5%)). Applying this analysis to the fuel economy improvements realized with the Hyperdrive-powered large SUV (16 mpg to 26 mpg), the present value of the fuel savings is $3,920. This compares favorably to the anticipated increase of $1,700 in system cost. (The panel also reviewed a simpler Case 2 in which fuel use over 3 years was evaluated, without discount. This case would yield savings over 3 years of $2,057, also greater than the anticipated increase in system cost.)

Building a cost competitive Hyperdrive system for large vehicles became possible only after commercial introduction of high voltage power semiconductors, specifically 1,400 Volt IGBTs. This occurred in 1998, the year we started building a prototype of the Hyperdrive. In Fig. 9 we present the "chain reaction" of effects of high voltage power semiconductors.

The existence of high voltage semiconductors offers the ability to make inexpensive and efficient DC/AC inverters. This in turn permits introduction of powerful traction motors. With powerful traction motors, elimination (or, in some cases, simplification) of the transmission is made possible. When using all these components, the Hyperdrive implements our new method of engine control to achieve near-maximum thermodynamic efficiency of spark-ignition engines (32 - 34% as compared to the maximum of 35%). There are also additional benefits of using lead-acid batteries at lower currents, such as increased operating life and lower cost.

The Hyperdrive is essentially an evolutionary improvement of the conventional gasoline (or diesel) powertrain. It uses the same component technology, but in substantially different ratios. The engine is smaller. The transmission is either eliminated or reduced. The starter motor and alternator become more powerful and larger in size and weight. The lead-acid battery is increased in size and weight. There are more powerful electronic power controllers than just existing voltage regulators: the DC/AC inverters. However, these inverters employ the same basic type of components that exist in vehicles today. The operation of all of the components is coordinated through a highly sophisticated powertrain computer controller, similar in nature to existing engine control modules from a components viewpoint. Thus, the Hyperdrive relies on very similar components very similar to those currently in use and the resulting system weight is almost identical. Altogether, this leads to total cost that is modestly greater than present powertrain configurations.

IV. Potential for Improvements in Fuel Efficiency

Based on the fundamental principles of thermodynamic efficiency, we believe that the fuel efficiency of our powertrain represents close to the practical limit of what is technically possible in passenger vehicles. We presented modeling results for three vehicles: a) compact car, b) full-size (large) car, and c) large SUV. Using the Hyperdrive system, a compact car exhibits an increase in combined fuel economy from 31 to 45 mpg (a 45% improvement), a full-size car exhibits an increase from 27 to 39 mpg (a 44% improvement), and a large SUV exhibits an increase from 16 to 26 mpg (a 62% improvement). We believe that these modeling results are representative of the type of increase that all vehicles subject to CAFE can produce using our powertrain.

Vehicles	Fuel Economy by Vehicle Type In CAFE Regulated Vehicles (mpg)		
	Conventional	Hyperdrive	Improvement
Automobiles			
Minicompact	26	44	**70%**
Subcompact	31	47	**51%**
Compact	30	48	**59%**
Midsize	27	43	**61%**
Large	25	39	**55%**
Two Seater	26	43	**65%**
SUVs/Light Trucks			
Small Pickup	22	30	**36%**
Large Pickup	19	28	**48%**
Small Van	23	31	**35%**
Large Van	18	28	**53%**
Small SUV	24	37	**57%**
Medium SUV	20	30	**45%**
Large SUV	18	25	**45%**

Table 6: Fuel economy in CAFE regulated vehicles (8,500 lbs. GVW and less) – selected conventional vehicles compared to comparable vehicles modeled with the Hyperdrive

To provide a more complete picture of the improvement in fuel economy that could be expected in other classes of vehicles, we identified the relevant characteristics of all of the vehicle categories listed in Table 2 (the categories defined in the Oak Ridge Transportation Energy Data Book and currently subject to CAFE regulation) and designed the Hyperdrive system for a *representative vehicle in each category*. A summary of our modeling results showing the original fuel economy of each representative vehicle, the fuel economy that results from incorporation of the Hyperdrive system, and the percentage improvement from such incorporation is provided in Table 6.[*] With potential fuel economy improvements of the magnitude shown here, application of Hyperdrive to a large volume of production vehicles would significantly reduce total gasoline consumption and consequently, the requirements for oil imports.

All of the fuel economy improvements presented herein are based only on the use of the new Hyperdrive power train. Further small improvements are still possible, such as through ICE engine optimization, but such improvements will be subject to the law of diminishing returns as the Hyperdrive is operating the engine within 1-3% of its possible maximum thermodynamic efficiency. Furthermore, improved fuel economy from the use of lighter materials, smaller aerodynamic drag, and lower resistance tires (those potential improvements discussed by the report of the Union of Concerned Scientists[4]) are not included in our analysis

[*] The three Hyperdrive vehicles modeled and presented in section 2 above were chosen to represent the Hyperdrive system as compared to the top performing vehicles for compact and full size (large) cars and the heaviest SUV subject to CAFE regulation. In Table 6, the Hyperdrive was modeled to be representative of the class as a whole. As a result, the fuel economy results for the categories "Compact Automobile", "Large Automobile" and "Large SUV" in Table 6 differ somewhat as compared to the results for the three specific vehicles selected and described above in section 2.

and would potentially result in additional improvements in fuel efficiency.

Of course, any HEV can only reduce overall fuel consumption in a meaningful way if it is commercially mass-produced. As discussed above, we believe that the Hyperdrive system has the only cost effective configuration of HEV that is fully scalable and is not cost prohibitive to mass-produce. As a first step toward the mass production of a Hyperdrive vehicle, our projections for cost will have to be substantiated through a manufacturing cost analysis of actual components in an actual vehicle that exhibits the performance and fuel economy advantages described above. Once cost projections are verified in the prototype vehicle, we would expect that participating automakers will begin the process of preparing for large-scale production of vehicles with the Hyperdrive system. If a development program were to begin now, automobiles with the Hyperdrive could be commercially introduced into the U.S. market within five years. We are hopeful that this process will commence in the near future in view of the level of interest being demonstrated by several leading automakers and key component suppliers.

It should be noted that such a transition will take substantial time to complete. To begin with, it will take Paice Corporation two years to deliver a complete demonstration vehicle and two additional years for the automakers to test and evaluate the vehicle and go through the expensive process of preparing for production. Once a vehicle with the Hyperdrive system appears on the market, subject to the level of customer acceptance and commitment on the part of the automaker, it will then take a number of years for the transition of the full range of the automakers vehicle lines.

While the Hyperdrive system can deliver fuel economy improvements of roughly 50 % across the full range of automobiles and light trucks, an additional question is in which vehicles is it most appropriate to begin implementing the Hyperdrive powertrain. We believe that the greatest fuel savings can be realized by introducing the Hyperdrive system into the SUV/light truck class of vehicles. To understand why this is the case, one must evaluate the issue of fuel efficiency under a gallons per mile analysis, as well as the traditional miles per gallon analysis.

As illustrated by Figure 10, under a miles per gallon (MPG) analysis, introduction of Hyperdrive technology results in an increase from 31 to 45 mpg for a compact car (a 14 mpg increase) as compared to an increase from 16 to 26 mph for a large SUV (a 10 mpg increase). Thus, from a MPG standpoint, it appears that greater value is added by incorporating the Hyperdrive powertrain into a compact car.

However, under a gallons per mile (GPM) analysis, those same increases in fuel efficiency result in dramatically different amounts of gallons used over 12,000 miles (one year of driving). As Figure 10 illustrates, using the Hyperdrive system in the same compact car yields a savings of 120 gallons per 12,000 miles. Conversely, using the Hyperdrive system in the same large SUV yields a savings of 290 gallons per 12,000 miles – more than double the fuel savings from the compact car.

While other factors bear on fuel economy, we feel that it is logical to focus on the number of gallons consumed for a specific distance traveled. Moreover, it makes sense that the Hyperdrive technology will yield the greatest per vehicle fuel savings when introduced into the SUV/light truck class of vehicles, because passenger cars are already more fuel-efficient than SUVs and light trucks and, therefore, don't have as much room for improvement. Consequently, if the goal is to yield the greatest fuel savings in the categories of vehicles currently on the road, the Hyperdrive system should be introduced first in the SUV and light truck vehicle class.

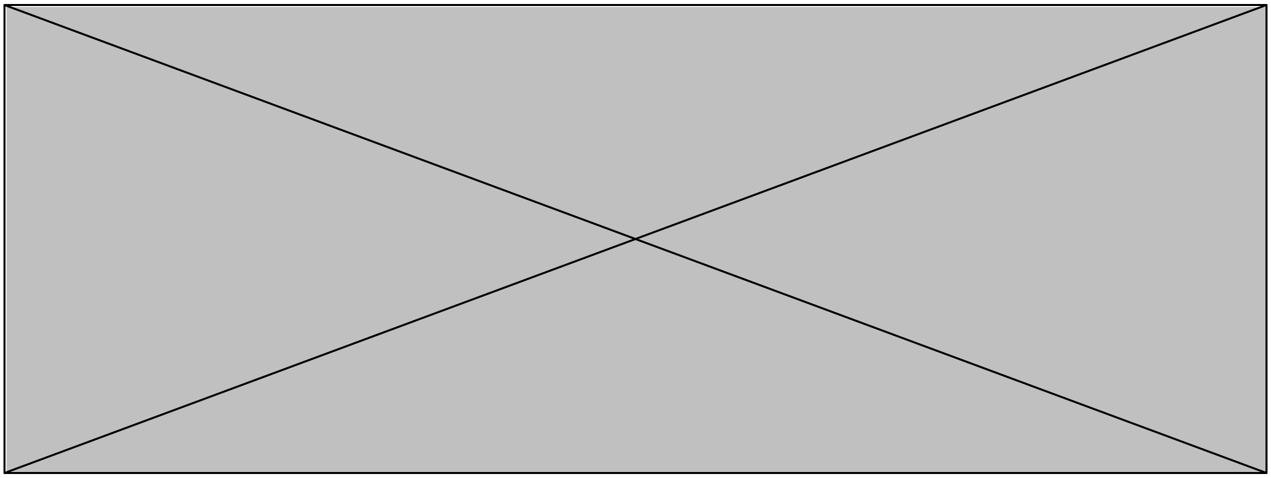

Figure 10: Comparison of a compact car and a large SUV on MPG and gallons of gas used over 12,000 miles

Additionally, we recommend that the Senate Commerce Committee ask Argonne National Laboratory to use its modeling software to corroborate our technical data and modeling. Their software is designed specifically for hybrid-electric vehicles and is able to match performance of physical models within 1-2% accuracy. It will allow the Government to corroborate our technical results without spending millions of dollars for physical prototypes, and will take weeks instead of years to complete. We also recommend that the Senate Commerce Committee take ANL's data and ask Oak Ridge National Laboratories, the originator of the report referenced in this testimony, to do a detailed analysis of the impact of the Hyperdrive on oil uses in the future. Paice Corporation is prepared to work with these national laboratories in performing such studies and to meet with the Senate Commerce Committee or other parties to discuss the results.

Conclusion

The Paice Corporation has designed and developed a hybrid electric powertrain, which results in ICE fuel efficiencies in the range of 32-34%, approaching the limit of thermodynamic efficiency for spark-ignition engines. Current automobile ICEs operate at around 18-22%, so the Hyperdrive has a potential to deliver significant gains in fuel economy.

We have successfully demonstrated fuel economy improvements in a full-scale prototype of the Hyperdrive on a dynamometer and used the data derived from such tests to model three selected vehicles, a compact car, a full-size car, and a large SUV. As compared to their conventional counterparts, the vehicles powered by the Hyperdrive exhibited an increase in combined fuel economy as follows:

Compact car - from 31 to 45 mpg (a 45% improvement)
Full-size car - from 27 to 39 mpg (a 44% improvement)
Large SUV - from 16 to 26 mpg (a 62% improvement)

The Hyperdrive is suitable for all vehicles covered by current CAFE regulations, and we believe that the modeling results presented are generally representative of the type of increases in fuel economy that can be realized in all vehicles subject to CAFE.

Regardless of the type of regulations imposed, Paice believes that national fuel consumption can only be meaningfully reduced in the long term if the auto industry can produce cars at acceptable cost that suit the needs and desires of consumers and that are at the same time highly fuel-efficient.

Hyperdrive cars will match or better the performance of existing vehicles. They will also have conveniences and features not feasible in present day cars. Hyperdrive cars will be more heavily dependent on real-time control software and other more advanced technologies than present ones and do things we can't even imagine now, as cell phones did just a few years ago. In a truly American way, they will save gas, and they will be better products.

We are confident that the Hyperdrive can be a valuable tool in enhancing fuel economy, improving our environment and reducing our dependency on foreign oil. We look forward to working together with the Government and the auto industry in achieving these goals.

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